Modeling Instruction in Physical Science: Effect on Student Achievement in Physical Science and Algebra I, Scientific Reasoning, and Attitudes Towards Science

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Abstract

Modeling Instruction is a constructivist, student-centered approach to teaching science, where students perform experiments to collect data and create models—mathematical, graphical, and diagrammatic—that represent the data. Students then test their models with more experiments, refining their models for use in various situations. Research shows that student achievement in science is higher for students participating in courses with Modeling Instruction at any grade level, but few studies have been done to determine the effect of Modeling Instruction on student achievement in both Physical Science and Algebra I. This research has the potential to improve science education by showing the effects of Modeling Instruction on student achievement in Physical Science and Algebra I, scientific reasoning ability of students, and attitudes by students towards science, adding to the research base in science education.

Keywords: Modeling Instruction, STEM Education, action research, Physical Science

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Chapter 1: Research Overview

Science, technology, engineering, mathematics: Together, these fields in education are combined into the acronym "STEM," which has become one of the most ubiquitous terms in education. A quick search of the term "STEM Education" returns "about 32,600,000 results" from the web tab and "about 9,750,000 results" from the news tab of Google (STEM Education, n.d.), and many of the results from the news tab reference articles describing multimillion dollar donations to many different organizations. From the sheer number and scope of these references, many groups have a vested interest in the quantity and quality of students who pursue careers in STEM fields. Further, due to the profound impact teachers have on students, these organizations have become very interested in teacher quality; for STEM education, the United States Department of Education alone has contributed 141.9 million dollars in 2013, 149.7 million dollars in 2014, and requested 319.7 million dollars for 2015 (U.S. Department of Education, 2014, p. 20).

With the rising interest in STEM education, all states have a coalition of organizations that work together to improve student achievement in STEM fields (State by State Initiatives, 2015). The state of South Carolina has the Coalition for Mathematics and Science, which "brings together advocates from business/industry, education, government and community organizations to catalyze action" (Mission & Vision, 2014). Many school districts, including Charleston County School District (CCSD), utilize curriculum designed by Project Lead the Way, "the nation's leading provider of K-12 STEM programs" (About PLTW, 2014). Laing Middle School in CCSD is a school that has utilized "aspects of STEM concepts in all academic curriculum since 2012," and "has been identified as one of the top middle schools in the nation for its interdisciplinary approach to teaching [STEM] subjects" (Kerr, 2015).

Physical Science and Modeling Instruction

Physical Science. The research for this dissertation will be completed in Physical Science, which is a course incorporating both introductory Chemistry and Physics. The first half of the course is the Chemistry section, in which students learn about atomic structure, chemical bonding, and reactions. The second half of the course is the Physics section, in which students study motion and forces, energy, and electricity. At the high school where the research will be performed, all ninth grade students take Physical Science, either at the Honors or College-Prep (CP) levels.

Historically at the high school where the research will be performed, Physical Science has been taught in a traditional manner: Information is presented to students through either live or video lectures, students complete worksheets related to the information, students perform prescriptive laboratory experiments, and quizzes and tests are used to measure the amount of content students retain. These methods were productive when South Carolina employed an End-Of-Course (EOC) assessment in Physical Science, because the South Carolina Science Academic Standards (South Carolina Department of Education [SC DoE], 2005) contained too much information to allow time for more in-depth study of the topics. However, the SC DoE made two major changes in 2014: The EOC assessment was switched from Physical Science to Biology; and, Physical Science was eliminated from the courses explicitly listed in the Academic Standards and Performance Indicators document (SC DoE, 2014). These changes from the SC

DoE, coupled with a broader shift in education towards more experiential learning methods, have altered expectations for teachers and students.

The problem of creating opportunities for students to meaningfully engage with Physical Science content and scientific processes is one that should be explored, and thoughtful consideration must occur within curriculum, instruction, and assessment. For curriculum, Charleston County School District has fashioned a set of academic standards and performance indicators from the Chemistry and Physics sections of the South Carolina Academic Standards and Performance Indicators for 2014. Difficult choices were made to reduce the number of topics within the Chemistry and Physics sections, and the remaining standards were intentionally selected to provide ample time for students to study the Chemistry and Physics content more deeply.

Within instruction, many choices that provide student engagement are available; one promising option seems to be Modeling Instruction, a hands-on, student-centered approach to teaching both the process and content of scientific disciplines. Modeling Instruction utilizes laboratory experiences to engage students in the science content to create a conceptual model, then students test and refine the conceptual model to determine its application and limits. The purpose of this study is to determine the effect of Modeling Instruction in Physical Science by analyzing student achievement in Physical Science and Algebra I, student ability to reason scientifically, and student attitudes towards science.

Modeling theory. This theory was first proposed by David Hestenes—a physics professor at Arizona State University—in 1987, with the help of a high school teacher, Malcolm Wells, and a doctoral student, Ibrahim Halloun (Hestenes, 2006, p. 2). Hestenes has been involved with the Physics Education Research (PER) community since its inception, and a principle concern "has been to establish a scientific theory of instruction to guide research and practice" (Hestenes, 2006, p. 1). Utilizing his background as a physics researcher, Hestenes

> identified construction and use of conceptual models as central to scientific research and practice, so [Hestenes] adopted it as the thematic core for a MODELING THEORY of science instruction. From the beginning, it was clear that Modeling Theory had to address cognition and learning in everyday life as well as in science, so it required development of a model-based epistemology and philosophy of science. (Hestenes, 2006, p. 1)

As modeling theories of scientific knowledge and cognition have become more mature fields in the last several decades, Hestenes and others have seen the disciplines intertwine to the point where they may be fully joined.

Modeling theory of scientific knowledge. To provide connections with modeling theory of cognition, modeling theory of scientific knowledge must have several key terms defined:

- System: A set of related objects. "Systems can be of any kind depending on the kind of object. … In a *conceptual system* the objects are *concepts*. In a *material system* the objects are material *things*" (Hestenes, 2006, p. 7).
- Structure: "The set of relations among objects in the system" (Hestenes, 2006, p. 7). In science, "all material systems have geometric, causal and temporal structure, and no other (metaphysical) properties are needed to account for their behavior" (Hestenes, 2006, p. 7). As stated by modeling theory, "science comes to know objects in the real world not by direct observation, but by constructing conceptual models to interpret

observations and represent the objects in the mind. This epistemological precept is called *Constructive Realism* by philosopher Ronald Giere" (Hestenes, 2006, p. 7).

- Model: "A *representation of **structure*** in a material system, which may be real or imaginary" (Hestenes, 2006, p. 7). Models exist in many different ways, depending on their function. "All models are idealizations, representing only structure that is *relevant* to the purpose, not necessarily including all five types of structure" (Hestenes, 2006, p. 7). Figure 1 provides a summary of the possible types of structure.

(a) **systemic structure**:
- ***composition*** (internal parts (objects) in the system)
- ***environment*** (external agents linked to the system)
- ***connections*** (external and internal links)

(b) **geometric structure:**
- ***position*** with respect to a reference frame (external)
- ***configuration*** (geometric relations among the parts)

(c) **object structure**:
- intrinsic properties of the parts

(d) **interaction structure:**
- properties of (causal) links

(e) **temporal (event) structure**:
- temporal change in structure of the system

Figure 1. Structures of a conceptual model in modeling theory of scientific knowledge. From "Notes for a Modeling Theory of Science, Cognition and Instruction" by D. Hestenes, 2006, *Proceedings of the 2006 GIREP Conference*. Copyright 2006 by David Hestenes. Reprinted with permission.

From these definitions many models may be created, and two useful models for scientific knowledge are: A mathematical model, representing the structure of a system by state and interaction variables; and, a process model, designating temporal structure as a change of state variables. These two models form the foundation of scientific theory, which is defined as "a system of general principles (or **Laws**) specifying a class of state variables, interactions and dynamics" (Hestenes, 2006, p. 8). Scientific process is governed by general laws that define the domain and structure of a theory and specific laws defining models. "The *content* of a scientific theory is a population of validated models," and a "model is *validated to the degree* that the measured values (data) match predicted values determined by the model" (Hestenes, 2006, p. 8).

Modeling theory of cognition. With the definitions of a conceptual model, a modeling theory of cognition may be created. Figure 2 provides information about the connection between the physical, mental, and conceptual worlds, and the theory rests on a "crucial distinction between mental models and conceptual models … Mental models are private constructions in the mind of an individual" (Hestenes, 2006, p. 10). Conceptual models are an encoded "model structure in symbols that activate the individual's mental model and corresponding mental models in other minds" (Hestenes, 2006, p. 11).

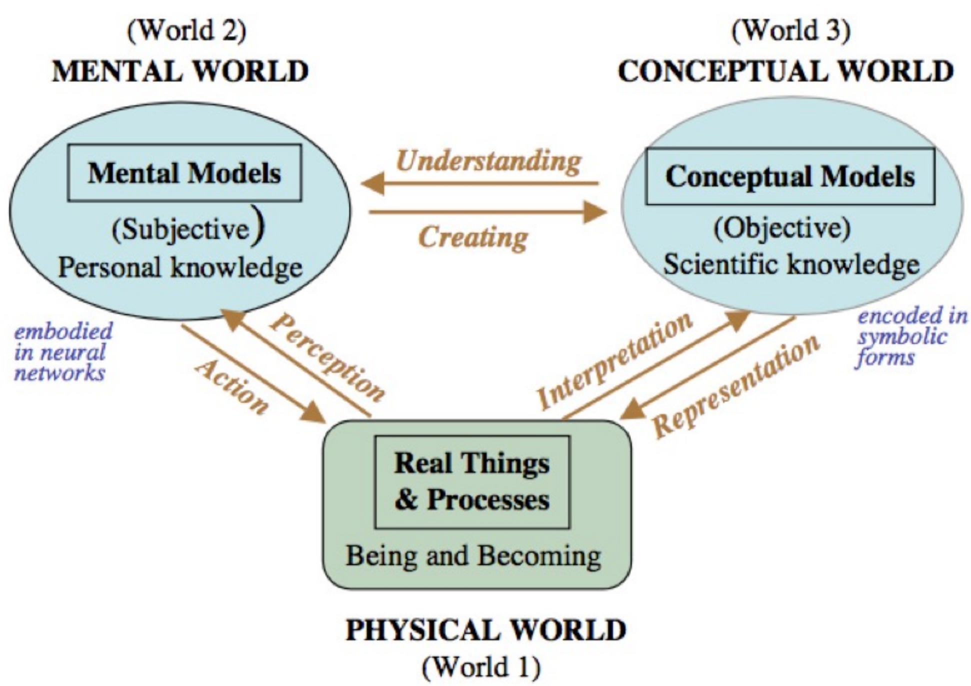

Figure 2. Relationships between the physical, mental, and conceptual worlds (Hestenes, 2006, p. 10). From "Notes for a Modeling Theory of Science, Cognition and Instruction" by D. Hestenes, 2006, *Proceedings of the 2006 GIREP Conference*. Copyright 2006 by David Hestenes. Reprinted with permission.

Connections between the three worlds highlight the manner in which they interact, and an understanding of these relationships provide an opportunity to connect the modeling theory of cognition with the modeling theory of scientific knowledge. The combination of modeling theories of scientific knowledge and cognition is simply known as modeling theory. Figure 3 describes how modeling theory drives instructional design, which informs teaching practice.

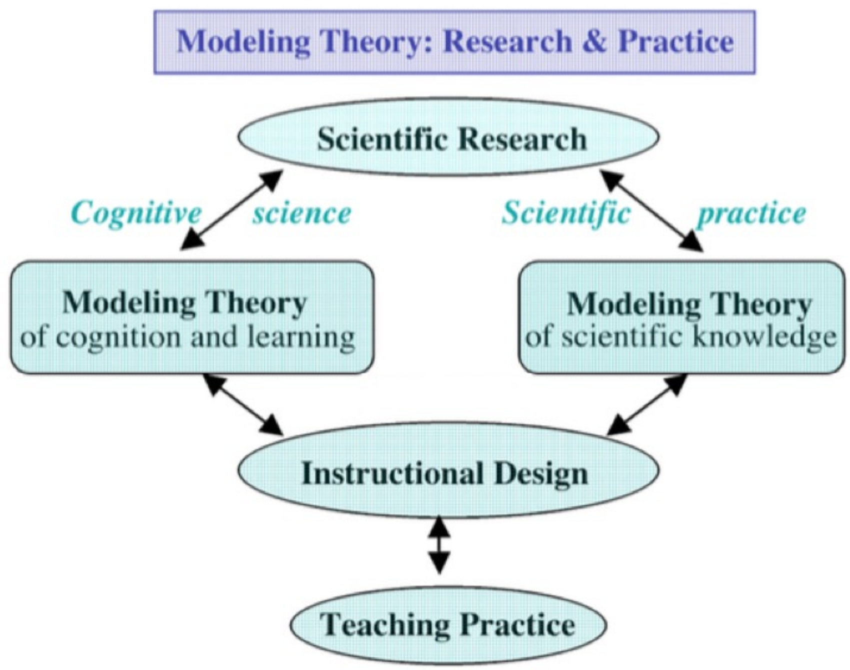

Figure 3. Relationships between modeling theory, cognition and learning, scientific knowledge, instructional design, and teaching practice. From "Notes for a Modeling Theory of Science, Cognition and Instruction" by D. Hestenes, 2006, *Proceedings of the 2006 GIREP Conference*. Copyright 2006 by David Hestenes. Reprinted with permission.

Modeling instruction. As indicated by the arrows in Figure 3, Modeling Instruction—the combination of instructional design and teaching practice—arises from modeling theory. "Modeling Instruction produces students who engage intelligently in public discourse and debate about matters of scientific and technical concern … and students in modeling classrooms experience first-hand the richness and excitement of learning about the natural world" (Jackson, Dukerich, & Hestenes, 2008, p. 10). According to Wells, Hestenes, and Swackhamer (1995), Modeling Instruction is based on the following instructional objectives and design:

Coherent instructional objectives

- To engage students in understanding the physical world by ***constructing and using scientific models*** to describe, to explain, to predict, to design and control physical phenomena.
- To provide students with ***basic conceptual tools*** for modeling physical objects and processes, especially mathematical, graphical and diagrammatic representations.
- To familiarize students with a small set of basic models as the ***content core*** of physics [and chemistry, biology, and physical science].
- To develop insight into the ***structure*** of scientific knowledge by examining how *models* fit into *theories*.
- To show how scientific knowledge is ***validated*** by engaging students in *evaluating* scientific models through comparisons with empirical data.
- To develop skill in all aspects of modeling as the ***procedural core*** of scientific knowledge.

Student-centered instructional design

- Instruction is organized into ***modeling cycles*** which engage students in all phases of model development, evaluation and application in concrete situations —thus promoting an integrated understanding of modeling processes and acquisition of coordinated modeling skills.

- The teacher sets the stage for student activities, typically with a demonstration and class discussion to establish common understanding of a question to be asked of nature. Then, in small groups, students ***collaborate*** in planning and conducting experiments to answer or clarify the question.
- Students are required to present and justify their conclusions in oral and/or written form, including a ***formulation*** of models for the phenomena in question and ***evaluation*** of the models by comparison with data.
- Technical terms and representational tools are introduced by the teacher as they are needed to sharpen models, facilitate modeling activities and improve the quality of discourse.
- The teacher is prepared with a definite ***agenda*** for student progress and ***guides*** student inquiry and discussion in that direction with "Socratic" questioning and remarks.
- The teacher is equipped with a ***taxonomy*** of typical student misconceptions to be addressed as students are induced to articulate, analyze and justify their personal beliefs. (p. 614)

Modeling cycle. As a framework for organizing instruction, the modeling cycle is instrumental for students to develop appropriate models that accurately describe the phenomena they study. The modeling cycle has two distinct parts: Model development, in which students perform a paradigm laboratory and engage in discussions to create a mental and conceptual model related to the physical world; and model deployment, during which students manipulate and test the model to determine the limits and applicability of the model. Throughout model deployment, students utilize written and verbal, graphical, diagrammatic, and mathematical representations to test the model. Assessments in the form of whiteboarding, quizzes, and additional laboratories are used formatively, and the modeling cycle is completed with a laboratory practicum and summative unit assessment.

One major aspect that separates Modeling Instruction from other instructional varieties is whiteboarding. The whiteboards are 24” x 36” erasable pieces that students use during all parts of the modeling cycle, giving students the opportunity to make their thinking visible around scientific content and processes. When performing laboratories, students record, graph, and analyze data on their whiteboard for presentation during the post-lab discussion. Having visible information from all groups allows students to compare, contrast, and question data and analysis easily, creating a robust discussion about the results. As students solve problems, “small groups of students write up their results … [and] have to account for everything they do in solving a problem” (Jackson, Dukerich, & Hestenes, 2008, p. 14). The students who are presenting are questioned by other students and the instructor to explicitly articulate their understanding, and any misconceptions are corrected through Socratic questioning.

Methodology

Research philosophy. To determine the extent student achievement is impacted by the interventions, curricula, and instructional methods, organizations utilize research to answer questions about their programs and provide evidence about the efficacy of the programs. Research may occur on the national, state, district, school, or teacher levels, and have a scope from thousands of teachers and students to a single teacher and students in one class. Historically, "research has been conducted primarily by professionals whose principal education included training in the conduct of research studies," but "more and more research is being conducted by *practitioners*--people whose primary education and training is *not* in research methodology" (Mertler, 2014, p. 4). A specific "type of practitioner-based research, known as *action research*," can be

> defined as any systematic inquiry conducted by teachers, administrators, counselors, or others with a vested interest in the teaching and learning process. … The basic process of conducting action research consists of four steps:
>
> 1. Identifying an area of focus
> 2. Collecting data
> 3. Analyzing and interpreting data
> 4. Developing a plan of action (Mills, 2011; Mertler, 2014, p. 4)

Once the plan of action has been implemented, the teacher-researcher will "make revisions and improvements to the project for future implementation, … [and] the effectiveness of the revisions would be monitored and evaluated, with new improvements developed for the next phase of implementation" (Mertler, 2014, p. 37-38). The cyclical nature of action research gives power to the teacher-researcher, because the teacher-researcher may build from previous research experience to make major changes and improvements for a particular course, department, or issue in a school.

Research site. The site for this study will be a large, suburban high school in the southeastern part of the United States. The high school has a student body of over 4,000 students, and the ethnic composition is 82% Caucasian, 12% African-American, 3% Hispanic, and 3% Other. Approximately 37% are served by gifted and talented program, and 6% are classified as students with disabilities. The high school has received an absolute rating of “Excellent” from the SC DoE from 2010 to 2014, and offers over 250 courses. These range from dance, choir, theatre, and band in the performing arts, engineering, mechatronics, horticulture, and others in the career and technical fields, and a comprehensive selection in mathematics, science, English, and social studies. The school has been very successful in many aspects: Academically, members of the class of 2015 were awarded over 24 million dollars in scholarships, 252 students received recognition from their performance on Advanced Placement (AP) tests, one senior was named National Merit Finalist, and eight seniors received appointments to a military academy; athletically, the school was named the 2014-2015 recipient of the state Athletic Administrators Association Director’s Cup for Class AAAA, given to the school with the best combined performance of all sports; and in the performing arts and career and technical education clubs, the school’s Marching Band won its ninth State Championship and finished seventh in the Grand Nationals competition, and the Culinary Arts Management Team won both the state and national competition. Many other clubs and teams achieved a high level of success, driven by dedicated and talented students, teachers, and coaches.

Participant selection. The participants of this study will be students, and their inclusion in the study will be determined by the placement of the student into one of the researcher’s Physical Science sections. The researcher should have between 2 and 6 sections of Physical Science at the Honors or CP levels, and each course typically contains 25 students. The total number of students will be between 40 and 120 students, which will provide a sample that is large enough to perform statistical analysis on the data collected.

Research questions and sources of data collection. This research will focus on three questions, all connected to the incorporation of Modeling Instruction within Physical Science. The data for Research Question 1 is all quantitative, Research Question 2 is both quantitative and qualitative, and Research Question 3 is both quantitative and qualitative.

1. What is the effect of Modeling Instruction in Physical Science on the achievement of ninth grade students in Physical Science and Algebra I? Data to be collected:
    - Grades and EOC scores from eighth grade mathematics and science courses
    - Simplified Force Concept Inventory (SFCI) scores at the beginning and end of the Physics section of Physical Science—30 minute assessment
    - Modified Math Concept Inventory (MCI) scores at the beginning and end of the Physical Science course—30 minute assessment
    - Physical Science District End-of-Course (DEOC) scores
    - Algebra I state EOC scores
2. What is the effect of Modeling Instruction in Physical Science on the scientific reasoning of students? Data to be collected:
    - Modified Classroom Test of Scientific Reasoning (CTSR) scores at the beginning and end of the Physical Science course—30 minute assessment
    - Interviews with students to determine their ability to coherently discuss science and mathematics concepts
3. What is the effect of Modeling Instruction in Physical Science on the attitudes of students towards science? Data to be collected:

- Colorado Learning Attitudes about Science Survey (CLASS) at the end of the Physical Science course—30 minute assessment
- Epistemological Beliefs Assessment for Physical Science (EBAPS) at the end of the Physical Science course—30 minute assessment
- Interviews with students to determine the impact of instruction on their attitude towards science

All data will be collected during the 2016-2017 school year, during the fall and spring semesters. The high school has a modified four-by-four block schedule, and Physical Science is a one-semester course. Therefore, some data collection will be completed at the end of the first semester and the rest at the end of the second semester.

Conclusion

Modeling theory provides a foundation for how humans learn scientific concepts, which leads to the manner in which science should be taught. Modeling Instruction has been created to align curriculum, instruction, and assessment with modeling theory, supplying a way to address student misconceptions and create accurate learning for each student. Because science and mathematics are intimately connected, Modeling Instruction should also increase the ability of students in mathematics. This study seeks to verify this idea and determine the extent to which Modeling Instruction affects student achievement in science and mathematics, student ability to scientifically reason, and student attitudes towards science.

Chapter 3: Methodology

To ensure reliability, validity, and replicability of the study, research methods should be carefully chosen. This study will utilize a mixed-methods research design known as an explanatory mixed-methods design, during which

> the educator-researcher first collects quantitative data and then gathers additional qualitative data in order to help support, explain or elaborate on the quantitative results (Cresswell, 2005). … When using this approach, the quantitative data and analysis provide the main focus for the overall study results; the qualitative data are used to elaborate on, refine, or further explain the quantitative findings. The emphasis is clearly on the quantitative data; qualitative data are typically used only to provide a closer look at outliers or extreme cases. (Mertler, 2014, p. 104)

The quantitative data will be collected using two different designs: Survey research, an aspect of descriptive design; and, one-group pretest-posttest design, a type of correlational design. “Survey research involves acquiring information from individuals representing one or more groups—perhaps their opinions, attitudes, or characteristics—by specifically asking them questions and then tabulating their response (Leedy & Ormrod, 2005)” (Mertler, 2014, p. 96). One advantage to survey research is that the design is relatively straightforward, because “the researcher poses a series of questions, usually in written form, to participants … Once the questions have been answered, the responses are aggregated across all the participants” (Mertler, 2014, p. 96). However, survey research does have a downside because “the researcher captures opinions and such, during a fleeting moment in time. The results should not be taken as a constant for the group surveyed—actions, perceptions, opinions, and even characteristics can change from one moment to the next" (Mertler, 2014, p. 97).

A one-group pretest-posttest design is in the family of preexperimental design, because the "independent 'variable' does not vary, largely because of the fact that there is only one group —since all participants in the study belong to the same group, there can be no 'group' comparisons" (Mertler, 2014, p. 100). This design is suitable because the goal of action research is to improve the practice of the educator instead of performing comparisons across teachers or schools. Action research is "characterized by as research that is done by teacher for themselves. It is truly a systematic inquiry into one's own practice (Johnson, 2008)" (Mertler, 2014, p. 4). A benefit of the one-group pretest-posttest design is that the researcher will "at a *minimum*, know if some sort of change has taken place (Leedy & Ormrod, 2005)" (Mertler, 2014, p. 102) and determine the size of change within the group. However, with no comparison group, the researcher may draw limited conclusions about the cause of the change; there may be other equally plausible explanations about the results.

Ethical Considerations

When performing any research, ethical considerations must remain in focus during the stages of research. "Keeping caring, fairness, openness, and truth at the forefront of your work as a teacher-inquirer is critical to ethical work" (Dana & Yendol-Hoppey, 2014, p. 150). A major consideration for this research is privacy, because data about many students will be collected. Personal identification will never be associated with a particular student when collecting the data, and student data will be reported in the aggregate to further ensure students cannot be individually identified. The school district explicitly provides an opportunity for students to opt out of any research without penalty, and also protects students from "possible physical, psychological, legal or other risks" (Procedures, 2015).

Another area of concern is the instruction students will receive. This research will use a teaching method with a group of students that is completely different from any of the current instructional methods, so there could be a disadvantage for those students who are in the classes of the teacher(s) who are using Modeling Instruction. However, in all the research discussed in the literature review, there is not a single case where students receiving Modeling Instruction have performed more poorly than the students receiving traditional or inquiry-based instruction. If this research shows positive effects on student achievement, the benefit to all future students outweighs any potential risks of this research.

Overview of Literature Review

Modeling Instruction has been shown to produce positive gains for student achievement on many different assessments, but the earliest research focused on student achievement on the Force Concept Inventory (FCI). The questions on the FCI "are based on a detailed taxonomy of *common sense (CS) concepts of force and motion* derived from research," and "each question requires a forced choice between a Newtonian [the correct] concept and CS alternatives for best explanation in a common physical situation" (Hestenes, 2006, p. 17). Figure 4 "summarizes data from a nationwide sample of 7500 high school physics students involved in the *Modeling Instruction Project* during 1995-98," and now there are "many examples of [modeling teachers] who consistently achieve posttest means from 80-90%" (Hestenes, 2006, p. 17).

Modeling instruction in ninth grade. Modeling Instruction has typically been implemented in ninth grade within a Physics course, because some schools and districts

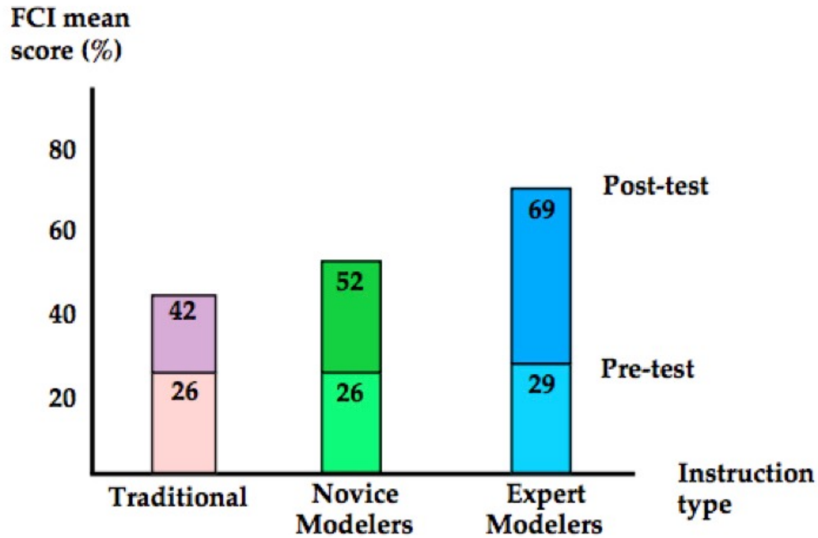

Figure 4. FCI mean pretest and posttest scores under different instruction types. From "Notes for a Modeling Theory of Science, Cognition and Instruction" by D. Hestenes, 2006, *Proceedings of the 2006 GIREP Conference*. Copyright 2006 by David Hestenes. Reprinted with permission.

throughout the United States are moving to a Physics-Chemistry-Biology course sequence. A study, conducted by Schuchardt et al. (n.d.) at an independent high school in Pittsburgh, Pennsylvania, compared ninth grade student performance in the areas of scientific reasoning and mathematical skills for students who completed one year of instruction in physics taught by a modeling-based instructional approach to one year of instruction in biology taught by an inquiry-based instructional approach. The study found that "students who have completed one year of instruction in modeling-based physics scored significantly higher on scientific reasoning and mathematical skills test when compared to ... students who have completed one year of instruction in inquiry-based biology" (Schuchardt et al., n.d., p. 1). Results from these two studies show a positive impact on student achievement with Modeling Instruction, though more quantitative and qualitative studies need to be completed for a better understanding of the impact of Modeling Instruction with ninth grade students.

Modeling Instruction in ninth grade: Physical science and mathematics. One study, performed by JoAnn Deakin (2006), implemented "portions of the 1st semester modeling physics curriculum that originated in the Modeling Instruction Program (2006) for high school teachers at Arizona State University." The purpose of the study was "to annotate the effects of modeling based physical science with 1st year algebra, 9th grade physical science students on their mathematics achievement" (Deakin, 2006, p. 2). Deakin reasoned that

> if students are taught from a modeling science curriculum they will be applying and reinforcing the concepts learned in algebra 1 because modeling requires students to construct the mathematical models they need. This would undoubtedly lead to greater success in algebra. (Deakin, 2006, p. 2)

Deakin used the Math Concept Inventory (MCI) to determine student achievement in mathematics, and the MCI is a "23-question test which covers basic math concepts that include aspects of scientific and mathematical reasoning, proportional reasoning, variable identification, data analysis, graphical interpretation, slope of a line, equation of straight lines, direct variations, averaging, measuring, estimating, and calculating volume" (Deakin, 2006, p. 5). Deakin administered the MCI to 105 students as a pretest and 103 students as a posttest, and "all students tested were enrolled in algebra I and had a variety of different math teachers. No students were second year math students and no students were enrolled in honors algebra" (Deakin, 2006, p. 6). The pretest data shows no statistically significant differences between Deakin and the controls, but

> *students in the control group show a 3.1% gain while [Deakin's] students show a 15.5% gain overall*. ... This difference is due to the heavy emphasis on linear equations, slope, y-

intercepts, etc. from the mechanics curriculum that students used in the second semester. (Deakin, 2006, p. 6)

The results of studies by Schuchardt et al. and Deakin show promise for a positive effect on the achievement of ninth grade students in both Physical Science and Algebra I, and this research will provide another opportunity for comparison.

Purpose Statement

The specific purpose of this study is to determine the effect of Modeling Instruction on student achievement in Physical Science and Algebra I, scientific reasoning of students in Physical Science, and attitudes of students towards science in Physical Science. The general purpose is to (a) test Modeling Instruction to determine if this method of teaching should be employed in more science courses and (b) improve the teaching and research ability of the researcher.

Problem Statement

The research questions for this study are:

1. What is the effect of Modeling Instruction in Physical Science on the achievement of ninth grade students in Physical Science and Algebra I?
2. What is the effect of Modeling Instruction in Physical Science on the scientific reasoning of students?
3. What is the effect of Modeling Instruction in Physical Science on the attitudes of students towards science?

Research Design

The research design for this study will be an explanatory mixed-methods design, and the researcher will collect quantitative data for all research questions before acquiring qualitative data for Research Questions 2 and 3. The sample for this research will be students who have the researcher for Physical Science at either the Honors or CP level, and the students are taken from the population of all ninth grade students at the high school. This population is both the sampling frame and accessible population for the research, and the theoretical population is all ninth grade students taking Physical Science in the United States.

Research question 1. This question will attempt to establish the effect of Modeling Instruction in Physical Science on the achievement of ninth grade students in Physical Science and Algebra I, using both a one-group pretest-posttest design and one-shot case study. Grades and standardized assessment scores will be collected from eighth grade mathematics and science courses to provide a baseline for students, and several assessments will be used as a pretest and posttest. These assessments are the Simplified Force Concept Inventory (SFCI) and a modified version of the Math Concept Inventory (MCI). The MCI will be given at the beginning of the course as a pretest and near the end of the course as a posttest, and the SFCI will be given at the beginning of the Physics section—approximately halfway through the course—as a pretest and near the end of the course as a posttest. For the one-shot case study, student scores on the Physical Science District End-of-Course (DEOC) and Algebra I End-of-Course (EOC) assessments will be collected and analyzed.

An analysis of data will be performed for the background information, SFCI pretest and posttest, MCI pretest and posttest, Physical Science DEOC and Algebra I EOC. Descriptive statistics, including mean, median, range, and standard deviation, will be utilized in the analysis, and correlational studies between background information, performance on the assessments, and between the assessments may be determined. This analysis will allow the researcher to draw conclusions about the effect of Modeling Instruction, though the conclusions will have little generalizability. The lack of a control group greatly reduces the statistical analysis that could show a high level of probable cause, but this is not a concern when performing action research.

Research question 2. This question will attempt to establish the effect of Modeling Instruction in Physical Science on the scientific reasoning of students in Physical Science using a one-group pretest-posttest quantitative design and case study qualitative design. A modified version of the Classroom Test of Scientific Reasoning (CTSR) assessment will be given at the beginning of the course as a pretest and near the end of the course as a posttest. The analysis will compare the descriptive statistics between the pretest and posttest and determine if any correlation exists between the background information of students and the results of the CTSR.

For the case study qualitative research, students at the upper and lower extremes of the pretest results will be interviewed at multiple times during the course to determine their ability to coherently discuss science and mathematics concepts. The researcher will use a structured interview process to determine how the student solves problems and characterizes information about Physical Science, and the interviews will be analyzed to detect any patterns. From the analysis of interviews, the researcher may determine the effect of Modeling Instruction on the scientific reasoning of students and this effect will be compared with the results from the quantitative method.

Research question 3. This question will attempt to establish the effect of Modeling Instruction in Physical Science on the attitudes of students towards science using a one-group pretest-posttest quantitative design and case study qualitative design. Two surveys will be given at the beginning and near the end of the Physical Science course: The Colorado Learning Attitudes about Science Survey (CLASS) and Epistemological Beliefs Assessment for Physical Science (EBAPS). The CLASS assessment was developed by researchers in the Physics Education Research group at the University of Colorado-Boulder, and the instrument “draws from existing surveys … and adds and refines material to account for other student [attitudes and beliefs] observed to be important in educational research” (CLASS Index, n.d.). The EBAPS was developed and validated at the University of California, Berkeley, and the assessment “is a forced-choice instrument designed to probe students' epistemologies, their views about the nature of knowledge and learning in the physical sciences” (EBAPS, n.d.). Analysis of the descriptive statistics from these assessments will allow the researcher to determine links between Modeling Instruction and student attitudes towards science, and the statistics from these studies may also be used in correlational analysis with the other data.

The case study qualitative research will follow the same pattern as Research Question 2; students at the upper and lower extremes of the pretest results will be interviewed at multiple times during the course to determine their attitudes towards science. The researcher will use a structured interview to discuss what the student believes about their ability to do science and other information they believe, and the interviews will be analyzed for patterns among the responses. After performing an analysis of the interviews, the researcher will determine the effect of Modeling Instruction on student attitudes towards science and compare this effect to the results shown by the quantitative study.

Conclusion

The design of this study utilizes both quantitative and qualitative components, though the quantitative aspect will be more heavily emphasized. This study seeks to determine the effect of Modeling Instruction in Physical Science by collecting data on assessments related to student achievement, scientific understanding, and attitudes towards science. Using descriptive statistics of the assessments and correlational analysis between background data and the assessments, the researcher will perform an analysis to understand the relationship between Modeling Instruction and each research question. Future research could include control groups and additional treatment groups to determine the effect of Modeling Instruction in varied situations, lending more support to those conclusions derived from this research.

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